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Consumption and utilization of dung by detritivorous and geophagous earthworms in a Danish pasture

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With 2 figures

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1. Introduction

Earthworms are saprophagous animals, comprising detritivorous species, which consume little decomposed plant remains, and geophages which consume relatively well decomposed plant remains (LEE, 1985). Unlike geophages many detritivores aggregate under mammalian dung (GUILD, 1951; SVENDSEN, 1957; HOLTER, 1979, 1983). This difference in behaviour raises the question: do the detritivores consume and exploit dung whereas the geophages do not? The evidence is ambiguous, since *Lumbricus rubellus* HOFMEISTER, *L. castaneus* (SAVIGNY) and *L. terrestris* L., normally regarded as detritivores as well as *Aporrectodea caliginosa* (SAVIGNY), normally regarded as a geophage, are supposed to consume and exploit dung (GUILD, 1955; BARLEY, 1959; MARTIN & CHARLES, 1979).

The objectives of this paper are to study the consumption and exploitation of cow dung by coexisting detritivorous and geophagous earthworms in a Danish pasture. Emphasis is on comparisons between the detritivorous *L. festivus* (SAVIGNY) and the geophagous *A. caliginosa*.

2. Materials and methods

2.1. Study area

The study was performed in a pasture known as Bøgemosen on the Strødam reserve 35 km north of Copenhagen. The soil is a dark fen soil, the *p*H is about 6.0, loss on ignition is 32.7%. The earthworm fauna of the pasture is briefly described by HOLTER (1983).

2.2. Ingestion

Ingestion of dung was measured with the aid of chromic oxide marked cowpats (HOLTER & HENDRIKSEN, 1987). Ten grams of chromic oxide was thoroughly mixed into 2 kg fresh cow dung using a Kenwood Major food mixer. Artificial cowpats of 2 kg marked dung (diameter 21 cm) were placed on nylon nets (mesh size 7 mm) in the pasture on day 830909. After 20 or 36 days the pats were removed and worms from below the pat were captured by digging and immediately killed in boiling water. After drying at 60 °C the presence of dung in the gut was measured by analysing the whole worm for the presence of chromic oxide (MCGINIS & KASTINGS, 1964). Worms containing more than twice the amount of chromic oxide found in controls (worms of the same species collected more than 100 m from the marked pats) were considered to contain dung.

2.3. Growth

Twelve cow pats were placed on nettings in the field on day 840903. After 20 days 12 plastic bowls (diameter 34 cm, height 16 cm, with small holes (max 3 mm) in the bottom) were dug into the turf with rims level with the

ground surface. The lower part of the bowls contained 2 cm of leca, on the top of this a block of turf was fitted into the bowl, and one of the cow pats was placed at the centre. Fifteen juvenile *Lumbricus* (mostly *L. festivus*) were added to each bowl, and the bowls were covered by a piece of netting (1 mm mesh size). After 2, 30 and 58 days 4 bowls were taken to the laboratory, the worms were handsorted from the turf, counted and identified.

In laboratory experiments bowls, with 2 cm leca at the bottom, were filled with soil from Bøgemosen (passed through a 4 mm sieve), and watered to about 80% water capacity. Eight bowls each received a pat of 1 kg made from 20 days old cow dung (aged at Bøgemosen). Ten or 8 juvenile *L. festivus* or *A. caliginosa* (from Bøgemosen) were added to bowls with dung or without dung. Before use, the worms were washed in water, dried with a piece of filter paper and weighed. After 40 days at 10°C the worms were handsorted from the bowls, counted, and weighed.

2.4. Cocoons

Eight 2 kg artificial pats, diameter 21 cm, each on a piece of netting (mesh size 7 mm), were placed with at least 2 m spacings in the field (on 840823). On the same day 19 cylindrical soil cores (diameter 7.6 cm, height 12 cm) were removed from between the pats. After 56 days the pats were removed and soil cores were removed according to the pattern shown in fig. 1. In addition, 8 cores were taken from between the pats. In the laboratory all cocoons were isolated from the soil cylinders: most of the soil was washed from the sample with a jet of water through a sieve (mesh size 1 mm). From the remaining material the cocoons were isolated by flotation in saturated magnesium sulfate. The cocoons were counted and identified. Unfortunately, cocoons of *L. festivus* and *L. rubellus* cannot be separated.

In the laboratory, pots (diameter 12 cm, height 14 cm) were supplied with 250 g soil from Bøgemosen (4 mm sieved), and watered to 80% water capapcity. To each pot were added 4 adult *L. festivus* or *A. caliginosa* (collected in Bøgemosen). Four pots with each species were supplied with 50 g of 20 days old (aged at Bøgemosen), 4 pots received no dung. After 30 days at 10°C the soil and remaining dung in the pots were searched for cocoons which were counted.

3. Results

3.1. Ingestion

L. festivus and *L. castaneus* consume dung, since 94.5% (95% confidence limits: 84.9–98.9, n = 53) and 87.5% (95% c.l.: 74.8–95.3, n = 48) of the analysed worms contain chromic oxide; while *A. caliginosa* only occasionally consumes dung, only 11.9% (95% c.l.: 4.0–25.6, n = 42) containing chromic oxide. The amounts of chromic oxide found in the worms constitute for *L. festivus* 6–50, for *L. castaneus* 3–11 and for *A. caliginosa* 2–6 times the amounts found in controls. Also, of the few *L. rubellus* (6) and *A. rosea* (Savigny) (5) captured and analysed, all *L. rubellus* but no *A. rosea* contained chromic oxide.

3.2. Growth

It appears from table 1 that *Lumbricus* species would mature in the presence of cow dung, but not *A. caliginosa*, since the proportion of adult *Lumbricus* increased from 27% to 62% during 56 days (G-test, H = 24.39, $p < 0.001$), while the proportion of adult *A. caliginosa* remained constant (G-test, H = 0.42, $p > 0.5$). *L. festivus* contributed 71.9%. *L. castaneus* 17.3% and *L. rubellus* 10.8% of adult *Lumbricus*. Mean temperature was 10.8°C during the first 30 days and 8.3°C during the last 28 days.

Further evidence that *L. festivus* is able to grow and mature in the presence of cow dung is supplied by table 2. The growth of *L. festivus* represents 1.8–2.2 times the initial mass, 90.5% survived and 29.7% mature in the presence of dung; in the absence of dung the corresponding values are: growth 0.9–1.1 times initial mass, 80% survival and no maturation. For *A. caliginosa* the figures are: in the presence of dung: growth 0.9–1.1 times initial values, all survive but 43.8% enter a quiescent state and none mature; in the absence of dung: growth 0.7–0.9 times initial values, 84.4% enter quiescence and none mature.

Table 1. Numbers of juvenile and adult *Lumbricus* and *Aporrectodea* after 2, 30 and 58 days' exposure to dung (numbers found in 4 bowls, see text).

Days exposed	juveniles	adults
Lumbricus		
2	73	27
30	56	43
58	35	57
Aporrectodea		
2	12	18
30	11	21
58	9	19

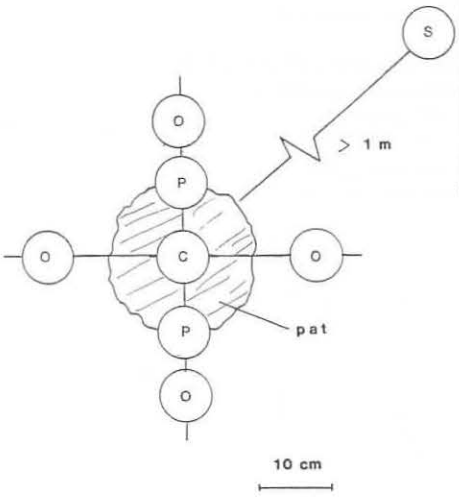
Table 2. Laboratory growth experiments with *L. festivus* and *A. caliginosa* with and without dung.

No.	*L. festivus*			*A. caliginosa*		
	Growth	Survivors	Adults	Growth	Survivors	Quiescent
+ dung						
1	742	10	6	3	8	3
2	721	7	4	11	8	4
3	611	10	1	− 4	8	5
4	481	10	0	−22	8	2
− dung						
1	92	9	0	−15	8	6
2	107	10	0	−13	8	8
3	−89	5	0	−54	8	5
4	75	8	0	−11	8	8

Growth (mean growth in mg of surviving individuals), numbers of survivors (out of 10 *L. festivus* and 8 *A. caliginosa*), numbers maturing during the experiment, and numbers (of *A. caliginosa*) entering quiescence.

3.3. Cocoons

The distribution and numbers of *L. festivus* and *L. rubellus*, *L. castaneus* and *A. caliginosa* cocoons found below 56 days old pats are shown in fig. 2. Below the pats (position C, P, O; fig. 1) there was no significant overall increase or decrease in the numbers of cocoons during the experiment for any of the species. However, the number of cocoons per unit area below the pats increased by a factor of 2.8 for *L. festivus* and *L. rubellus* cocoons, and 7.4 times for *L. castaneus*, but decreased 0.6 times for *A. caliginosa* (position C, P; fig. 1) as compared to soil outside pats. The lack of significance can probably be attributed to the contagious distribution of the cocoons in each position below and around the pats, especially for cocoons of *Lumbricus* species, reflected by the high $s^2/\bar{x}$ ratios. Cocoons of *L. castaneus* and *A. caliginosa* appear non-randomly placed in the positions below and around pats (Kruskal-Wallis tests; *L. castaneus*, $H = 10.120$, $p > 0.025$; *A. caliginosa*, $H = 18.160$, $p > 0.001$), this may also hold for *L. festivus* and *L. rubellus* ($H = 3.807$, $p > 0.1$). Fig. 2 suggests that more *L. castaneus* cocoons are found in the P-position and more *A. caliginosa* cocoons in the O-position. In the 83 soil cores analysed an additional 7 cocoons of *A. rosea* were found. No cocoons were found in the dung. The numbers of adult earthworms found below the pats and their immediate surroundings ($0.125\ m^2$) were 3.4 ± 1.6, *L. castaneus*, 5.1 ± 1.9 *L. rubellus*, 16.3 ± 2.5 *L. festivus* and 4.1 ± 2.1 *A. caliginosa;* in the soil from outside pats the numbers were: 0.5 ± 0.9 *L. castaneus*, 0.8 ± 0.9 *L. rubellus*, 2.3 ± 1.4 *L. festivus* and 4.5 ± 1.4 *A. caliginosa*.



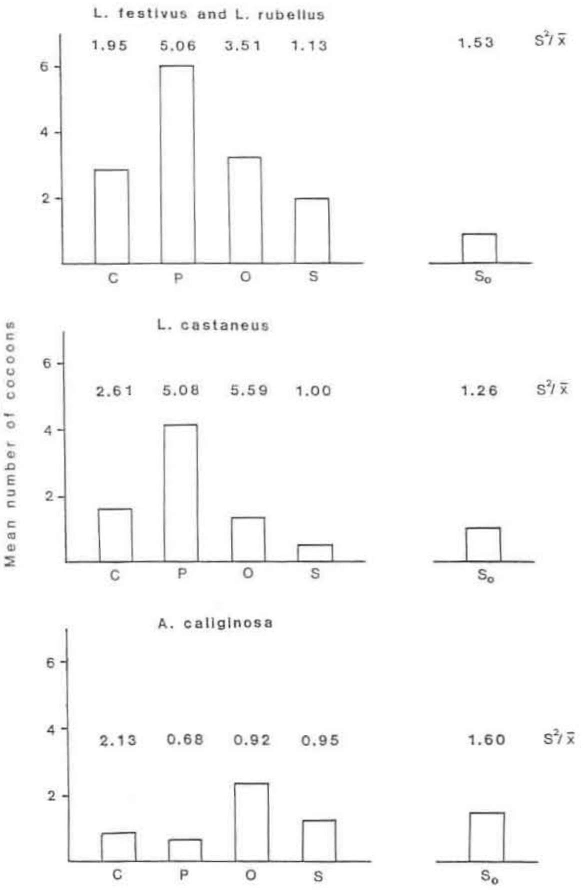


Fig. 1. The positions of soil cores below and around the cow pats.

Fig. 2. Mean number of cocoons of *L. rubellus* and *L. festivus*, *L. castaneus* and *A. caliginosa* in different positions below and around cow pats (see Fig. 1) aged 56 days. The mean number of cocoons found in the pasture at the start of the experiment (S_0) is also shown. The ratio $s^2/\bar{x}$ is for every position and species shown above each column.

The numbers of cocoons produced by 4 ind. of *L. festivus* during 30 days at 10 °C in laboratory cultures were 15.0 ± 2.4 in the presence and zero in the absence of dung. The corresponding values for *A. caliginosa* were: 5.0 ± 1.6 and 3.2 ± 1.3. In the presence of dung 31.2% of *A. caliginosa* entered quiescence, while 56.3% did so in the absence of dung.

4. Discussion

The earthworm population of Bøgemosen consists of the species: *L. castaneus, L. festivus, L. rubellus, A. caliginosa* and *A. rosea*. The three *Lumbricus* species agregate below cow pats, while the two *Aporrectodea* species do not (Holter, 1983). Study of gut contents shows that *L. castaneus* and *L. rubellus* are detritivores (Piearce, 1972, 1978) and *A. caliginosa*, (Piearce, 1972, 1978) and *A. rosea*, (Bolton & Phillipson, 1976) are geophages. Similar results are not available for *L. festivus;* but results presented here show that it is a detritivorous species, aggregating below low cow pats and consuming dung. The geophagous species, in contrast, seem only occasionally to consume small amounts of dung.

The detritivores, mostly exemplified by *L. festivus*, exploit the cow pats, since they grow, mature and produce cocoons in the presence of dung in the field as well as in cultures. This is in full accordance with results obtained for different detritivores offered various kinds of mammalian dung as food in cultures (EVANS & GUILD, 1948; GUILD, 1955; HARTENSTEIN & AMICO, 1983; LOFS-HOLMIN, 1985).

The geophagous species, exemplified by *A. caliginosa*, do not exploit the cow pats. This is at variance with results obtained by BARLEY (1959) and by GUILD (1955), who grew *A. caliginosa* on dung and well decomposed manure, respectively, and MARTIN and CHARLES (1979) who concluded that cattle dung was consumed by *A. caliginosa*. However, BARLEY (1959) found that the growth of *A. caliginosa* was faster when the dung was incorporated into the soil, as opposed to surface applied. The conclusion from this may be that *A. caliginosa* behave differently to different kinds and ages of dung or comprises ecologically different morphs (SIMS & GERARD, 1985).

Obviously, detritivores as well as geophages produce cocoons below cowpats, in their immediate surroundings and freely in the field; but the results also suggest that detritivores produce more cocoons below the pats. This could result from increased abundance of worms below the pats or from increased productivity of cocoons. HOLTER (1983) shows that *L. castaneus* starts leaving the pats when more than about 6 weeks old, while *L. rubellus* and *L. festivus* stay longer. Probably this means that a reasonable value of cocoon production per adult *L. festivus* and *L. rubellus* could be calculated, since the incubation time of cocoons is estimated as 8–20 weeks (EDWARDS & LOFTY, 1977).

Such calculations suggest that 8 cocoons are produced per adult below the pats (position C, P, O; fig. 1) and 16 cocoons in the free soil; hence the production rate of cocoons seems not to be increased by the presence of dung. This unexpected result could be explained by migration of worms between the pats and an associated production of cocoons during the migration.

The distribution of cocoons below the pats suggests that *L. castaneus*, *L. rubellus* and *L. festivus* spend more time below the periphery than below the central part of the pats. *A. caliginosa* seems to prefer the area surrounding the pats. The reason for these distribution patterns are unknown.

HOLTER (1983) found a strong positive correlation beween earthworm biomass and the disappearance of cow pats, later shown to be effected by a bulk transport of organic matter from the pats (HOLTER & HENDRIKSEN, 1987, 1988). The results presented here suggest that this strong correlation results from the consumption of dung by detritivorous earthworms.

Although GUILD (1955) suggest that dung is one of the most valuable foods for earthworms, it can be concluded that the detritivorous and geophagous earthworms coexisting in Bøgemosen do not compete for dung as a food.

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In a Danish pasture the earthworm fauna consists of three detritivorous species: *Lumbricus festivus, L. castaneus* and *L. rubellus* and two geophagous species: *Aporrectodea caliginosa* and *A. rosea.*

The detritivores, mostly exemplified by *L. festivus,* consume and utilize cowdung; the utilization expresses itself in growth and cocoon production. The geophages, exemplified by *A. caliginosa,* on the contrary, consume dung only rarely, and they seem not to grow or produce cocoons when dung is the only available food.

Both groups of earthworms produce cocoons below cow pats in the field, and as a consequence of aggregation by detritivorous earthworms under the pats, there are an increased number of cocoons below the pats compared to the surrounding "free" soil.

The distribution pattern of cocoons under and surrounding the pats, indicate that the detritivorous earthworms mostly stay below the periphery of the pats, while *A. caliginosa* seems to prefer the soil surrounding the pat.

It is concluded that it is the detritivorous earthworms, which have an important impact on cowpat disappearance and decomposition and that the coexisting detritivorous and geophagous earthworms in a pasture do not compete for dung as food.

Keywords: *Lumbricus festivus, Aporrectodea caliginosa,* consumption, utilization, cow dung, earthworm cocoons, coexistence.

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